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## AERIAL VISUAL SHAPE DISCRIMINATION AND MATCHING-TO-SAMPLE PROBLEM SOLVING ABILITY OF AN ATLANTIC BOTTLENOSE DOLPHIN

by N. K. W. Chun  
Biosciences Department

May 1978

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Using a simultaneous matching-to-sample paradigm, two-dimensional geometric shapes of various configurations were presented to a bottlenose dolphin in an aerial visual discrimination task. Large differences in perimeter lengths between any two types of shapes presented together generally resulted in better discrimination performance. Alternatively, small differences in perimeter lengths of any two shape types presented together generally resulted in poor discrimination performance. The absence of a monotonic function between perimeter differences and performance accuracy indicated that other form parameters may be contributing factors in the discrimination process.		

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→ Data were collected to determine if position biases influenced response behaviors. The results were negative. Stimulus preference was also shown to have little effect on choice-making by the dolphin.

Complete changes of the discriminanda were made to assess conceptual learning by the dolphin, and the results indicated that transfer did not occur between sets of stimuli when subsequent sets of geometric shapes differed greatly from the previously learned set. Comparison of baseline data with a reacquisition curve of the same problem presented 6 months later clearly indicated a function typical of problem-specific rather than conceptual learning.



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## I. INTRODUCTION

Ten years have elapsed since Kellogg and Rice's (1966) shape discrimination experiment was conducted, measuring visual discrimination and the problem solving ability of the bottlenose dolphin. The study paved the way for other investigators by engendering interest in the area of dolphin vision. Cetacean vision studies have been sparse in comparison to the voluminous work compiled in the field of echolocation.

The present experiment was designed to test the ability of the Atlantic bottlenose dolphin (*Tursiops truncatus*) to visually discriminate between two-dimensional stimuli of differing geometric patterns in a matching-to-sample paradigm. In addition to shape discrimination, its objective was to gain some insight into the conceptual learning ability of the dolphin by examining its ability to apply a learned concept (matching-to-sample) to different stimulus conditions. Investigation into the dynamics of visual discrimination used by the dolphin is also discussed.

### A. Background

There seems to be much disagreement about whether or not the dolphin possesses good visual acuity. Some authors (Matthissen 1886, and Dawson, Birndorf, and Perez, 1972) indicated that the vision of the Atlantic bottlenose dolphin is extremely myopic in air. On the other hand, Slijper (1958), and Caldwell and Caldwell (1972), argued that the dolphin possesses good vision both in water and in air. They are supported by the performances of dolphins in various aquaria which demonstrate the ability to leap into the air to execute behaviors which require a high degree of visual proficiency.

Gross anatomy studies by Dawson, et al, (1972) indicated that the dolphin has better visual acuity under bright light conditions. Their explanation is based upon the idea that constriction of the double-slit pupil permits only a narrow beam of light to pass through the centermost portion of the lens. This process allows the light rays to converge closer to the retinal surface than would otherwise be possible if the pupil were wider. Since dolphins are capable of producing tightly constricted pupils and also possess an acute retinal light sensitivity, the light rays are not refracted to a great extent, and a clearer image on the retina is thus produced.

A dolphin eye model, developed by Rivamonte (1976) showed that displacement of about 3mm of the lens was necessary to compensate for the refractive power of the cornea in air. The dolphin does not possess the physiological mechanism to alter the shape of the rigid lens, therefore pupillary constriction provides the retinal image quality necessary for in-air vision.



In a test of visual acuity, Pepper and Simmons (1973) presented Ronchi rulings to a bottlenose dolphin at a distance of 2.8 m. The threshold value obtained was equal to 18 minutes of arc, a minimum visual angle considerably poorer than that reported for pinnipeds (Schusterman, 1972).

Herman, Peacock, Yunker and Madsen (1975) collected aerial visual acuity data from the dolphin at two different distances (1.0 m and 2.5 m). Measurements were taken separately for each eye (monocular vision), and aerial acuity, measured in minutes of visual angle, was found to be superior at the 2.5 m distance.

Using basic two-dimensional shapes (triangles, circles and squares), Milberg and Pepper (1975), investigated the acquisition of matching-to-sample behavior to evaluate the visual discrimination and learning capability of the bottlenose dolphin. In a continuation of the matching-to-sample experiment, the present study evaluated both the dolphin's perceptual capacity and its ability to apply the concept of matching pairs to a number of different stimulus conditions. The results of this report reflect data collected over a ten-month period.

## II. METHODS

### A. Subject.

The subject was a 140 kg, 2.4 m female Atlantic bottlenose dolphin (*Tursiops truncatus*), approximately 11 years old, which participated in the investigation of the acquisition of visual matching-to-sample. No visual anomalies were revealed by an ophthalmoscopic examination of this animal prior to testing. The dolphin displayed good pupillary reflex and oculomotor rotation in tracking objects visually. Retinal vascularity appeared normal and the cornea and lens were perfectly clear.

The dolphin was maintained on a diet of Columbia River smelt (*Thaleichthys pacificus*) and mackerel (*Scomber scomber*). Daily consumption varied from 6 to 9 kg, with more than one-third of the daily intake earned during the experimental sessions. The subject was approximately 21 hours food-deprived prior to each session. Reinforcement during the training sessions consisted of smelt only.

### B. Apparatus.

The dolphin was housed in a 6.0 m by 6.0 m floating pen with a 2.4 m draft (cf. Steele, 1971). The training cubicle from which the operator conducted the experiment was mounted on a floating platform and attached to one side of the pen. The operator could visually monitor the behavior routine of the animal through a small porthole in the front of the cubicle.

Located below the porthole was a stimulus display board, 36 cm high and 215 cm across. The geometric shapes were presented on this display board, which was hidden from the dolphin's view between trials by a sliding panel.

Three response manipulanda were attached to 360° switches located directly above each geometric shape and spaced 50 cm apart. Each manipulandum was constructed of .6 cm diameter stainless steel tubing, inserted into a rubber hose approximately 30 cm long. When viewed by the dolphin, the manipulanda extended directly in front of each form on the display board (Figure 1). The geometric shape in the center position was designated as the sample or standard, to which the left or right alternative was matched by properly deflecting the appropriate manipulandum.

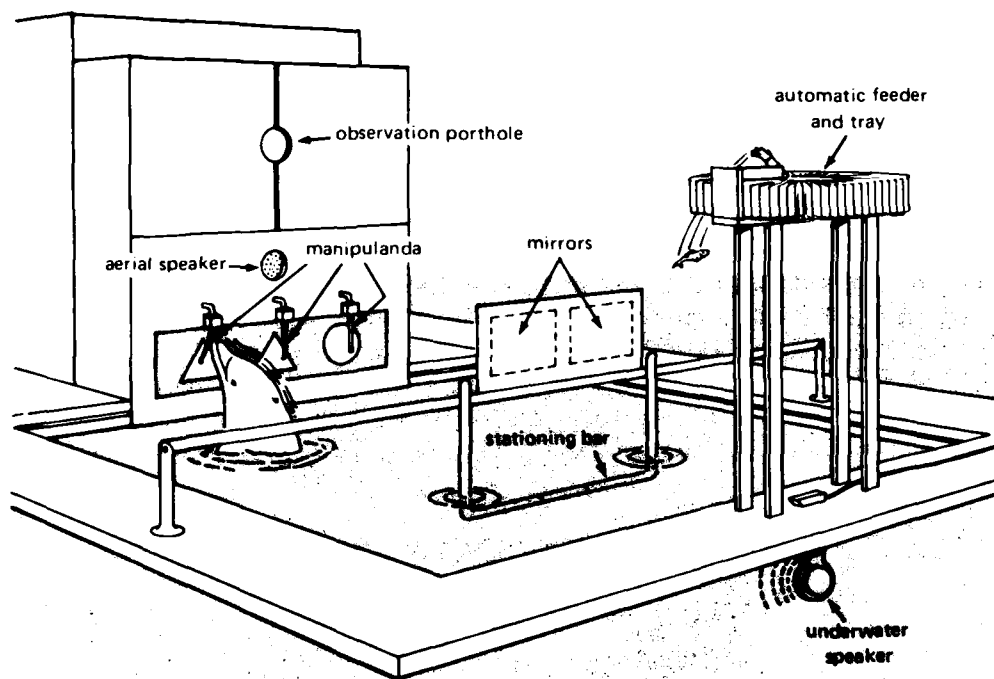


Figure 1. Sketch of experimental layout.

A stationing bar was positioned 2.8 m from the display board and submerged 8 cm underwater. This apparatus was constructed of galvanized pipes secured to a horizontal support beam which extended across the pen. A neoprene foam pad was attached to the bar to cushion the dolphin when stationing. Two mirrors mounted directly above the stationing bar further enabled the operator to visually monitor the animal's performance.

A Davis Scientific Universal feeder (model 320) was located on the side of the pen opposite the stimulus display board (Figure 1). Underwater signals were transmitted via a University Sound speaker (model UW-30) submerged under the automatic feeder at a depth of 60 cm. Aerial signals were delivered by a University Sound speaker (model 2UW) mounted centrally above the stimulus display board.

The equipment that was used to record responses was housed in a van located dockside near the dolphin's pen. This equipment included a Hewlett-Packard calculator (model 9810 A), a Davis Instrument Co. relay panel, a Hewlett-Packard coupler/controller (model 2570 A), and a Sony Corp. integrated stereo amplifier (model TA-1055).

The operational format was pre-programmed on magnetic cards. This program controlled all peripheral equipment. Selection of a specific session format, also programmed on magnetic cards, enabled the operator to choose any one of a number of trial sequences. The calculator recorded responses and latencies in addition to controlling the onset of the station (8-kHz) and reinforcement (12-kHz) tones. The release (10-kHz) tone was manually controlled by the operator in the training cubicle by manipulation of a switch on a control box. This operation was not automated to assure that the dolphin was in proper position to observe the visual stimuli before being required to respond. Each tone was delivered simultaneously by the aerial and underwater speakers.

A series of lights on the control box designated the operational stage of each trial sequence. The latencies were displayed on a digital clock and were measured from the onset of the release tone to the dolphin's response to either alternative manipulandum.

Six sets of geometric forms were used as the discriminative stimuli, with three types of geometric forms in each set (Figure 2). To control for the effects of differential brightness, all forms were painted white and were constructed with equal surface areas ( $323 \text{ cm}^2$ ). The stimuli were presented on a black background to insure optimal visibility contrast. On any given trial, only two of the three types of geometric shapes in each set were presented—a matched pair and an incorrect alternative. Twelve different problem configurations were constructed by using different combinations of the geometric forms from an individual

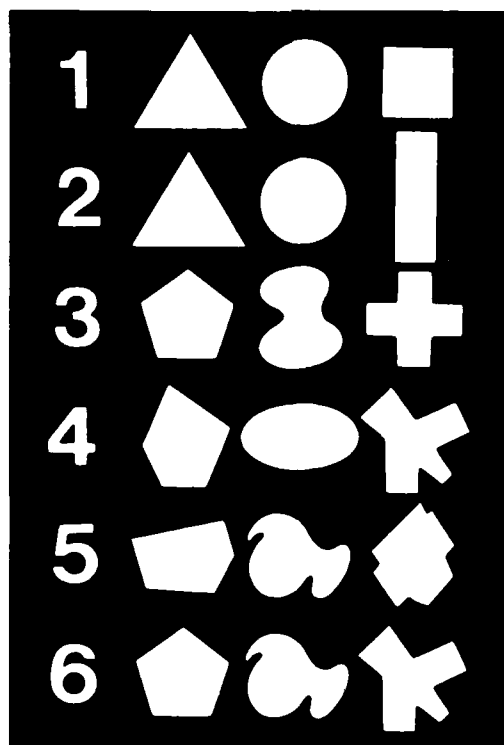


Figure 2. Sets of geometric forms used.

set. The problem configurations in Set 1, for example, using triangles, circles, and squares, are shown in Figure 3, with the center form as the sample. Code numbers were assigned to each of the twelve combinations and arranged randomly. Each code were presented five times, totaling 60 reinforced trials per session.

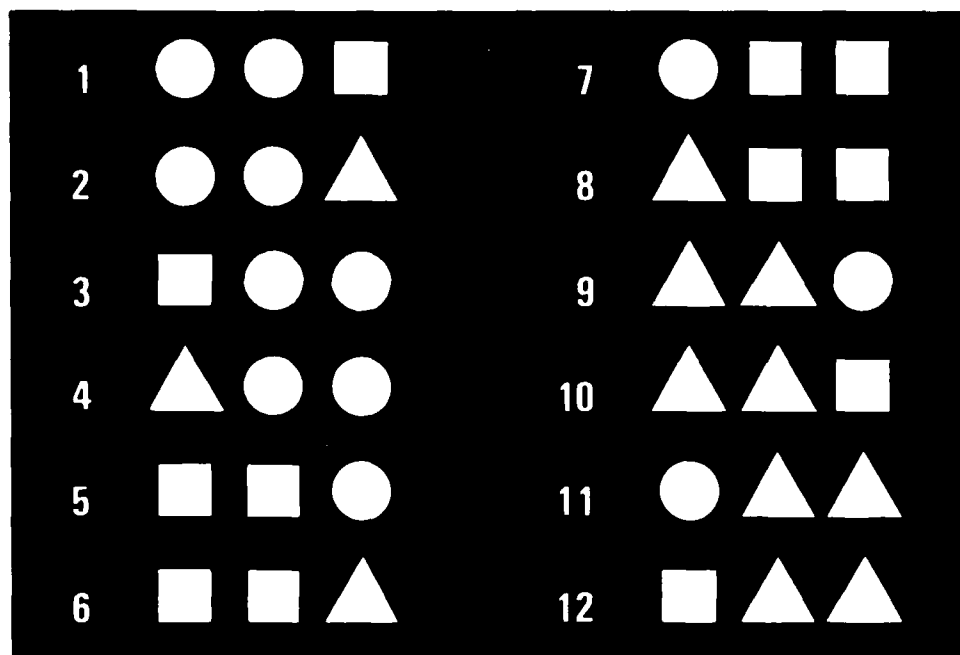


Figure 3. Twelve problem combinations and assigned code numbers (Set 1).

The population of geometric shapes used was categorized into three groups to investigate the possibility that a distinctive type of shape was inherently more discriminable than others. All of the shapes in this experiment, therefore, could be classified in one of three stimulus-domains: triangular or pentagonal, smooth-edged or circular, and boxed or cross-like.

There was only one geometric form change made in Set 2. Sets 3, 4, and 5 were comprised of completely novel discriminative stimuli to evaluate the ability of the dolphin to transfer the concept of matching-to-sample in solving similar shape discrimination problems. Set 6 included discriminative stimuli which had been presented previously in Sets 3, 4, and 5.

#### c. Procedure.

The dolphin was required to position her head on the stationing bar upon hearing the 8-kHz station tone. When the proper position on the stationing bar was assumed by the dolphin, the sliding panel was manually lifted by the operator, exposing the forms on the display board for approximately 3 seconds. The 10-kHz release tone was then initiated, instructing the dolphin to swim to the display board, depress the center manipulandum,

and match the sample by properly deflecting the manipulandum which corresponded to the correct alternative stimulus (Figure 4a, b, c). Correct responses were followed by the delivery of a single smelt and the onset of a simultaneous 12-kHz tone which served as the conditioned reinforcer. Deflection of either alternative manipulandum (correct or incorrect) ended the trial and was followed by a 30-second intertrial interval (ITI).

A correction procedure was implemented in which an incorrect response resulted in presentation of the same problem until the dolphin made the correct response. Subsequent presentations of an incorrect trial were considered as training trials and were recorded, but were not used in the data analysis. The correction procedure proved to be invaluable, as it minimized the influence of position biases.



Figure 4a. Subject stationing.

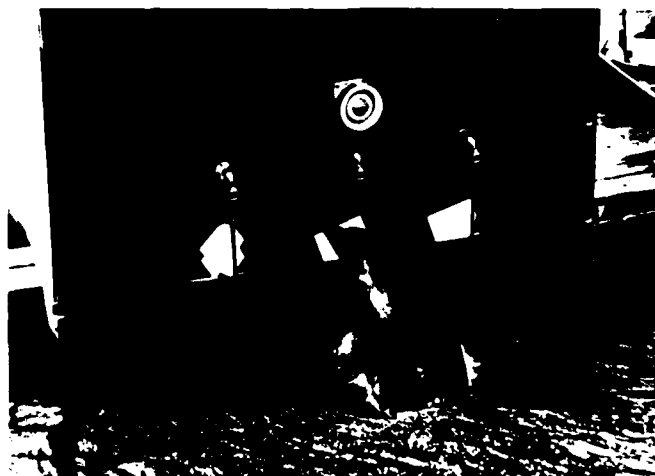


Figure 4b. Subject tripping sample manipulandum.

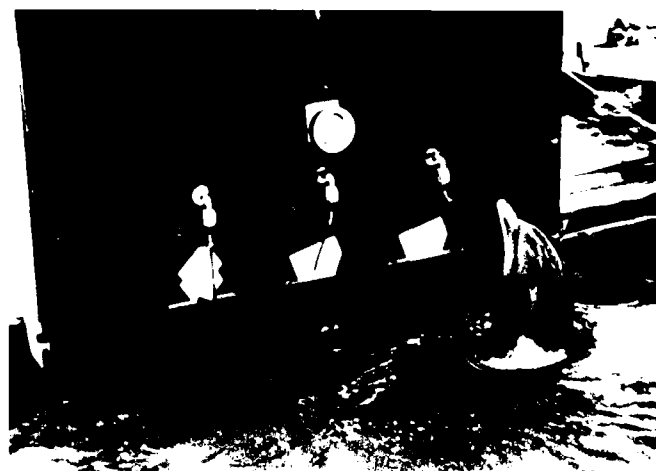


Figure 4c. Subject tripping correct alternative manipulandum.

An additional response contingency required the dolphin to respond to the alternative manipulandum within 5.5 seconds after the onset of the release tone. A response made after this period resulted in a "time-out" which was recorded and treated as an error.

The daily performance was recorded on data sheets which corresponded to the program that was fed into the calculator prior to each session. This gave the operator a quick reference of the presentation sequence. Data sheets were prepared using ten different sequences, which were numbered and presented in order. A large number of different sequences was used to eliminate any sequential learning variables.

Records of responses were also collected during each session from calculator print-outs. Information from the calculator print-out was transferred to keypunch cards which were then fed into a computer. By using a selected computer subplot routine, specific behavior information could be extracted from the data and plotted on graphs or tables.

Each session included a minimum of 60 reinforced trials, which ran from two to three and one-half hours, depending upon the number of correction trials presented. The experimental sessions were conducted five days a week.

### III. COMPARISON OF RESULTS

#### A. Set 1 (▲●■)

Set 1 included 70 sessions and three months of data collection. The tables of the composite scores in this section were derived from the performance curves of each set shown in the Appendices. All of the problems involving two of the same shapes were compiled together, disregarding position variables (see Discussion). For example, to obtain the triangle-circle composite score, the average scores of Codes 2, 4, 9 and 11 (see Figure 3) were tabulated. The 12 possible combinations of shapes were arranged into three groups of discriminative stimuli to analyze basic perceptual differences between individual geometric

forms. By comparing the composite scores with the discriminative stimuli, the level of difficulty of discrimination between any two forms could be quantified. The groups of discriminative stimuli and their corresponding composite scores are shown in Table 1.

Table 1. Composite scores (Set 1).

Discriminative Stimuli	Composite Score
▲●	87.2
▲■	64.0
●■	72.9

In set 1, problems which required the dolphin to discriminate between triangle and circle (regardless of which shape served as sample or alternative) contained a higher percentage of correct performances than those problems which required the dolphin to discriminate between triangle and square or circle and square. The most perceptually difficult problems for the dolphin to solve were those which required discriminations between triangle and square.

Learning did occur, and this was reflected by the ascending function in all of the performance curves in the set (see Appendix A). However, the learning rate progressed very slowly, with problems involving squares consistently the most difficult in this set.

#### B. Set 2 (▲●|)

The square was replaced by a rectangle in the second set to examine corresponding changes in performance. This strategy effected a substantial increase in performance accuracy attributed to both learning development and the relative ease of the new discrimination task. In Set 2, problems which required the dolphin to discriminate between triangle and circle once again contained a higher percentage of correct responses than those problems which required discriminations between triangle and rectangle or circle and rectangle. The composite scores for the triangle-rectangle and the circle-rectangle performances increased 20.6 and 20.4 percent, respectively, over the triangle-square and the circle-square performance in the first set (see Table 2).

Table 2. Composite scores (Set 2).

Discriminative Stimuli	Composite Score
▲●	96.8
▲	84.6
●	93.3

c. Set 3 (●●+)

Tests for conceptual transfer characteristically require altering more than one controlled aspect of the stimulus. In set 3, all of the discriminative stimuli were changed in order to compare the effect of such a manipulation to that produced by changing only one discriminative stimulus as was done in Set 2. The objective of this test was to evaluate the ability of the dolphin to transfer the previously learned concept of matching pairs to a totally novel stimulus condition.

Transfer of the matching concept did not take place. The results of the first five sessions revealed chance-level performances ( $\bar{x} = 57.6$ ) which indicated that the dolphin was learning the task on an intra-problem basis rather than by forming a concept or rule which could be used to solve a variety of matching-to-sample problems.

Substantial increases in performance scores were noted in those problems in which crosses were presented with other shapes (see Appendix C). From essentially chance level performance, the dolphin demonstrated a remarkable capacity to learn these problems in only nine sessions.

The most difficult problem for the dolphin to solve were those in which the pentagon and the smooth-edged form were presented together as either standards or alternatives. A composite score of 52.4 percent indicated that the dolphin was not able to acquire a discrimination between the two stimuli. The performance curve for this problem contained a wide range of percentage scores ( $SD = 11.9$ ) with no ascending tendency; whereas the performance scores of problems involving crosses were representative of typical learning curves.

Discrimination performance appeared to be largely affected by the differences in perimeter lengths of the stimuli. Geometric shapes which were closely matched in judged complexity (nearly equal perimeter lengths) were generally more difficult for the dolphin to discriminate. On the other hand, those shapes which had large differences in perimeter lengths (complex forms in contrast to simple forms) were more readily solved. Table 3 shows the relationship of performance accuracy and perimeter length differences for this set.

Table 3. Composite scores in comparison to perimeter differences (Set 3).

Discriminative Stimuli	Composite Score	Perimeter Difference (cm.)
●●	52.4	12.7
●+	85.4	27.9
●+	82.6	15.2



D. Set 4 (●●✕)

Set 4 was designed to examine changes in the performance accuracy as a result of manipulating the perimeter length differences.

The results are shown in Table 4. The five-sided form and the smooth-edged form, having only a difference of 3.8 cm, could not be discriminated visually by the dolphin. The performance curve was marked by a comparatively high degree of variability and remained near chance even after 21 sessions (see Appendix D).

The five-sided form-cross (33.0 cm difference) and the smoothed-edged form-cross (34.3 cm difference) problems on the other hand were quite easily solved by the dolphin. Although the relationship between the composite scores and perimeter length differences was not a consistently linear one, supporting data suggest that gross differences in perimeter length was associated with more efficient visual shape-resolution capability.

Table 4. Composite scores in comparison to perimeter differences (Set 4).




Discriminative Stimuli	Composite Score	Perimeter Difference (cm.)
●●	60.2	3.8
●●✕	98.4	33.0
●●✕	95.7	34.3

E. Set 5 (●●●)

The continuing accuracy of performance by the dolphin in problems involving crosses, prompted an investigation to determine whether selections were indeed made on the basis of perimeter differences rather than due to some other perceptual cue, such as degree of angularity, which effected better resolution performance. If perimeter length was the relevant perceptual cue used in the discrimination process, stimulus preference for crosses would probably have very little influence on choice-making by the dolphin.

The stimuli in this set were therefore constructed so that the smallest difference in perimeter length was between the cross and the five-sided form, and the largest difference in perimeter length was between the five-sided form and the smooth-edged form.

Table 5. Composite scores in comparison to perimeter differences (Set 5).




Discriminative Stimuli	Composite Score	Perimeter Difference (cm.)
	91.5	20.3
	79.7	5.1
	76.7	15.2

As expected, performance accuracy in problems involving crosses decreased, indicating that stimulus preference had a negligible effect in the visual discriminative process, and that responses were more directly influenced by the perimeter differences between the geometric shapes presented. Here again, problems which contained shapes which were grossly unequal in perimeter lengths were perceptually the least difficult to discriminate.

#### F. Set 6 ()

The results from Set 6 gave additional support to our hypothesis, but the non-linear relationship between perimeter length differences and performance accuracy once again indicated that other form parameters were involved in the discrimination process. Unfortunately, in shape discrimination experiments such as in this one, many variables interact simultaneously, and a singular independent variable such as perimeter length cannot be isolated from the influence of other stimulus properties.

Table 6. Composite scores in comparison to perimeter differences (Set 6).

Discriminative Stimuli	Composite Score	Perimeter Difference (cm.)
	61.1	22.9
	99.0	34.3
	88.6	11.4

The number of sessions required to reach asymptote in each set declined steadily from the start of the experiment, with the exception of Set 2, in which only one discriminative stimulus was changed. The dolphin demonstrated an ability to adapt to changes in the stimulus conditions more readily after exposure to many different types of problems. Performance was facilitated by this exposure and is evidenced by the reduction in the number of sessions required to reach asymptote in each subsequent set.

Set 6 was also used in conjunction with Set 2 in an experimental test of conceptual learning which is discussed in Section IV.

#### IV. DISCUSSION

##### A. Luminance.

The brightness variables affecting the appearance and perception of the discriminative stimuli were not optimally controlled, as the experiment was conducted out of doors in ambient sunlight. However, discriminations between the positive and negative stimuli within each trial presented an equal level of difficulty for the dolphin. The effect of differential brightness on performance accuracy was not analyzed.

##### B. Position Bias.

In a simultaneous matching-to-sample experiment, Cumming and Berryman (1965) reported that some pigeons display an almost complete position habit in the initial learning of the shape discrimination. Herman and Arbeit (1973) examined the influence of position bias in a dolphin tested on a successive auditory discrimination learning-set task. The error rates of the left and right responses were compared under different sequences of the positive stimulus (S+ first and S+ last). No evidence of position responding was found, even though substantially higher error rates occurred when the positive stimulus was presented first in the sequence.

As a test of position bias in this experiment, the percentage correct of left responses and the percentage correct of right responses were compared (Figure 5). No systematic position habit in the dolphin was revealed by these curves, and reasonably uncontaminated results could be expected in the composite scores.

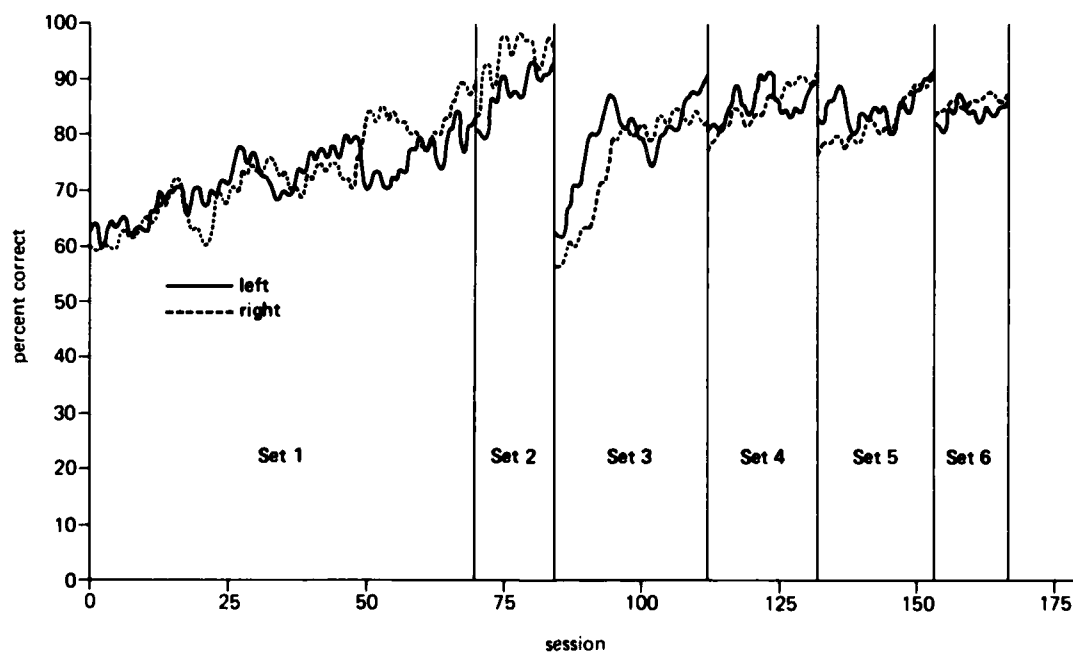


Figure 5. Comparison of percentage correct left and right.

Unlike the matching-to-sample experiment with the pigeons, this experiment employed a correction procedure in which errors resulted in the repetition of the trial until the correct response was made. Such a procedure extinguishes any position habit the subject may develop early in training (Cumming, et al., 1965). A prolonged correction procedure may induce an alternating second response in a two-choice discrimination task if the initial response is incorrect (White, Spong, Cameron, Bradford, 1971); however, this behavior was extinguished prior to the start of the experiment.

### C. Form Parameters as Predictors of Discrimination Performance.

The underlying parameters which were common to the highly discriminable forms were examined in terms of the perceptual characteristics of the stimuli. The discriminative aspects of the stimuli were initially examined in terms of differences in angularity, compactness, number of sides, and perceptual complexity – stimulus properties which are essentially non-quantitative. The problems of quantification were compounded because of the interactive effects of these parameters, and because of the inability to isolate one parameter as the independent variable. Unlike discriminations based on size and brightness (transpositional parameters), form parameter (transitive) variables do not reduce well to quantification, and are governed by theories of Gestalt psychology.

In applying information theory to the measurement of form parameters, Attneave (1951, 1954) and Attneave and Arnoult (1956) demonstrated that information about a two-dimensional geometric form was concentrated at its contour. Perimeter length has often been used as an index in the scaling of perceived complexity and as a predictive variable in the discriminative performance of geometric shapes. The relationship between the perimeter length and the perceptual complexity of stimuli was shown in Stenson's (1966) factor analysis of the dimensional characteristics of 20 random forms. Of the four parameters which described physical complexity (Stenson's Factor "D") perimeter length was given the highest factor loading.

The functional relationship of contour, stimulus complexity, and discrimination performance was also examined by Polidora (1965) and by Polidora and Thompson (1964, 1965) using metric patterns as visual stimuli in shape discrimination experiments with rhesus monkeys. In an analysis of their experiments, Zusne (1970) commented:

"Although these studies suffer from a number of methodological problems, they definitely show that discrimination improves with increasing difference in complexity between the positive and negative stimuli. When random forms are used, difference in complexity is the most readily utilized discriminative clue in all animal species with which complexity has been used as an independent variable."

### D. Concept Learning.

Herman and Gordon (1974) reported on the ability of an Atlantic bottlenose dolphin to form a delayed matching learning set. A successive auditory discrimination task was employed as the experimental design using a playback procedure to minimize the influence of sequential preferences. They found convincing evidence in support of conceptual transfer by the bottlenose dolphin in the acoustic modality.

In the present experiment, the assessment of the conceptual learning ability was conducted using a simultaneous matching-to-sample paradigm presented in the visual mode. This evaluation was conducted by comparing an established baseline performance level with a re-acquisition curve of the same problem presented six months later. Set 2 (triangle, circle, rectangle) served as the test problem as it met three important criteria of the test design: high performance level ( $\bar{x} = 91.6$ ), low variability of performance scores ( $SD = 3.8$ ), and temporal displacement from the original test. The results of the baseline data indicated that the dolphin was psychophysically capable of discriminating between triangles, circles and rectangles.

The re-test trials were presented as probes, disguised in the normal sequence of trials in Set 6. These trials were distributed evenly across 20 sessions, with approximately one probe in each block of 10 trials. This small ratio was used to minimize the effect of learning, thereby revealing more accurate transfer data. A total of 120 probe trials were presented to the dolphin. The reinforcement contingencies during baseline remained in effect during transfer testing; that is, a correct response to a probe trial resulted in the presentation of the conditioned reinforcer paired with food reinforcement.

The results of the test are shown in comparison to the previously established baseline scores from Set 2 data (Figure 6). Initial performances on the probe trials were near chance and gradually increased to the level of the baseline mean only after 15 sessions and 900 total trials (90 of which were probe trials). The performance curve of the dolphin's re-acquisition data clearly indicated that the concept of matching was not transferred and that matching-to-sample using visual test stimuli was learned on an intra-problem basis. The accuracy of performance by the dolphin using different visual test stimuli appeared to be highly dependent upon the degree of change of relevant perceptual cues.

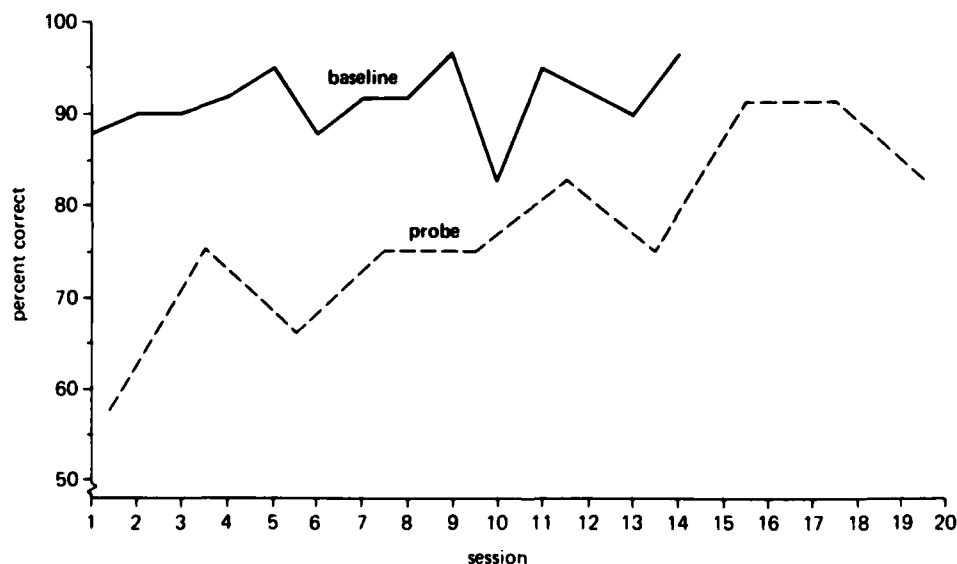


Figure 6. Comparison of baseline performance with probe trials.

#### E. Summary.

Aerial visual acuity of the dolphin by human standards is poor. It has been experimentally tested and found inferior to pinniped vision. Large differences in perimeter lengths between two geometric patterns of the same surface area were found to be an influential factor affecting discrimination performance within any set. Conversely, geometric patterns which had equal or nearly equal perimeter lengths generally resulted in poorer discrimination performance. The absence of a monotonic function between perimeter differences and performance accuracy indicated that other form parameters may be involved in the discrimination process. Tests were conducted to determine if stimulus preference influenced choice selection. The results were negative.

By changing more than one shape in a discriminative set, a progressively larger decrement in performance can be expected. However, greater exposure to a large number of stimulus conditions enabled the dolphin to adapt to change more readily and facilitates performance in subsequent tasks.

No systematic position preference was found in the dolphin, possibly resulting from the implementation of a correction procedure.

Completely novel sets of discriminative stimuli were presented to the dolphin to evaluate conceptual learning. Transfer did not occur between sets when geometric shapes differed greatly from the previous set. Comparison of baseline data with a re-acquisition curve of the same problem suggests a function typical of problem-specific rather than conceptual learning.

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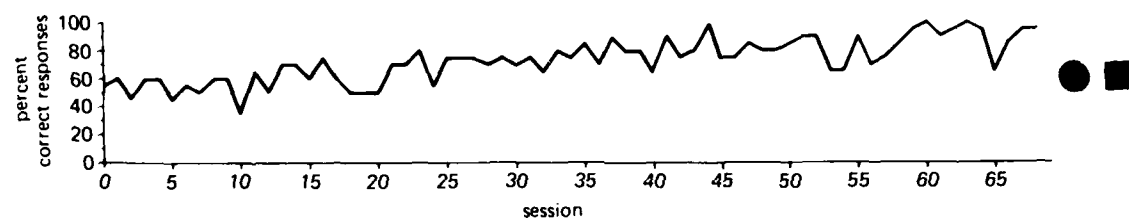
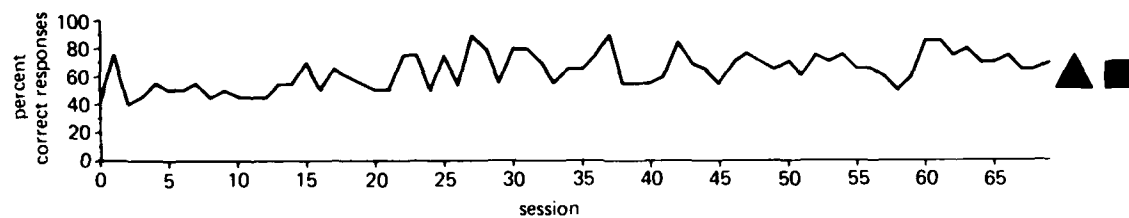
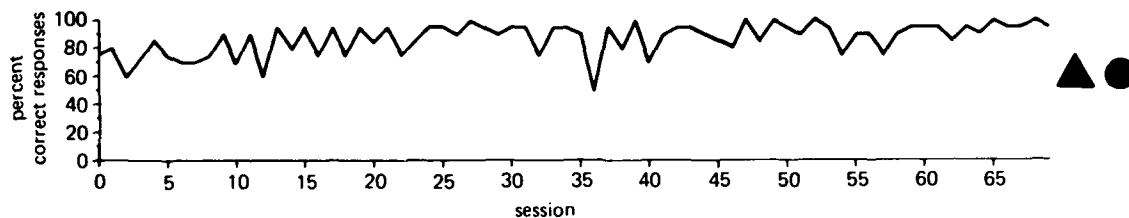
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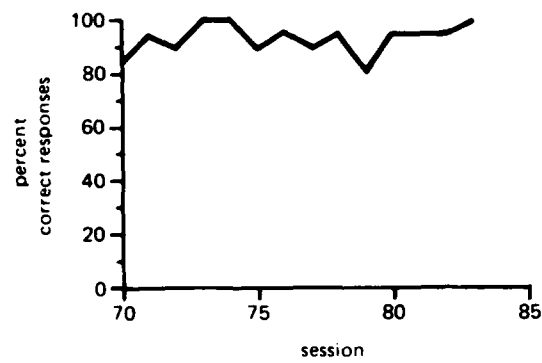
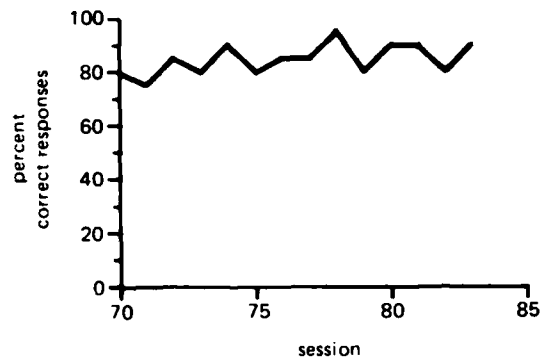
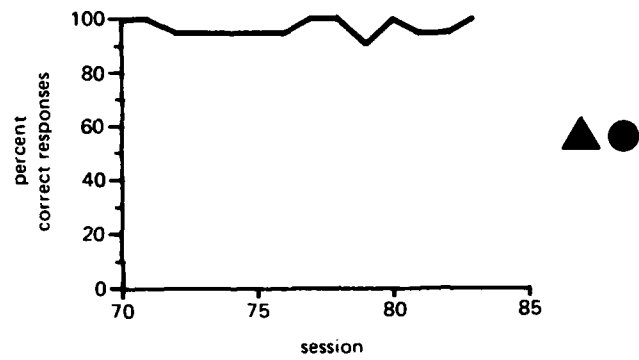
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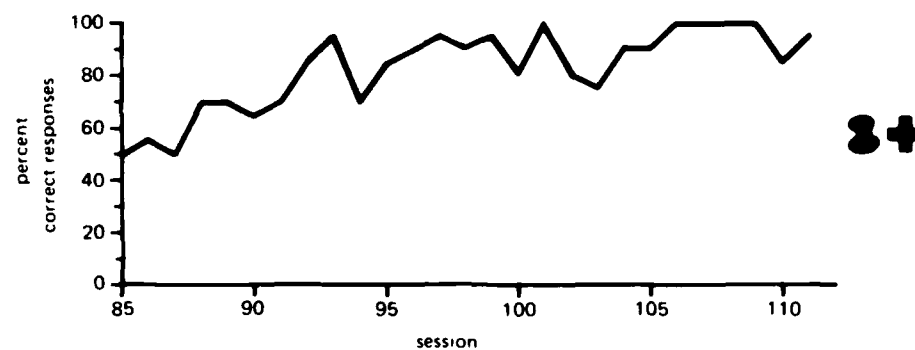
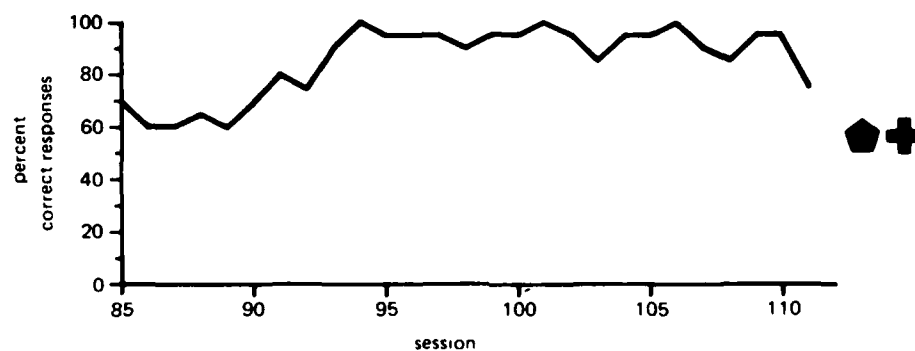
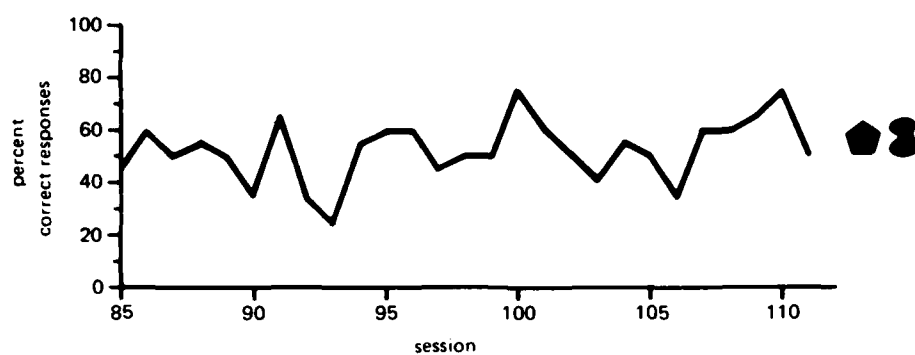
# APPENDIX A: Performance Curves - Set 1



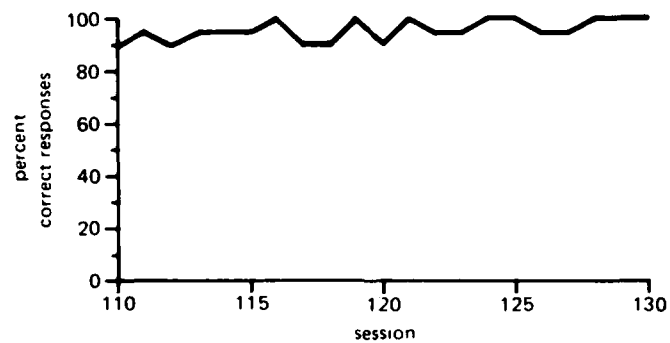
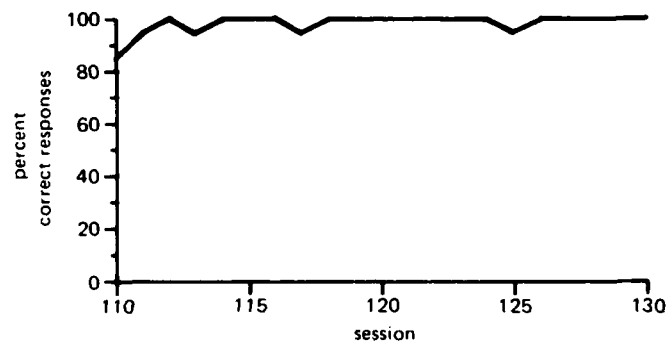
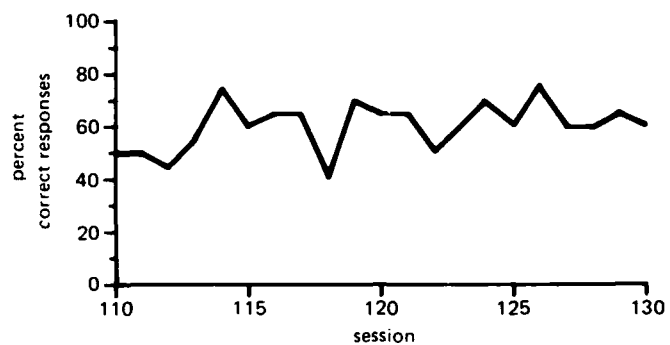
# APPENDIX B: Performance Curves - Set 2



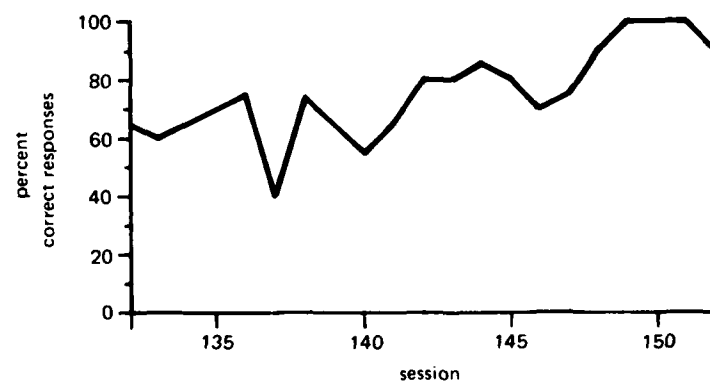
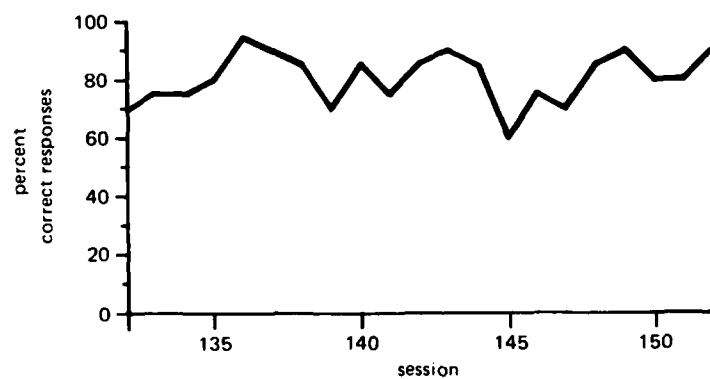
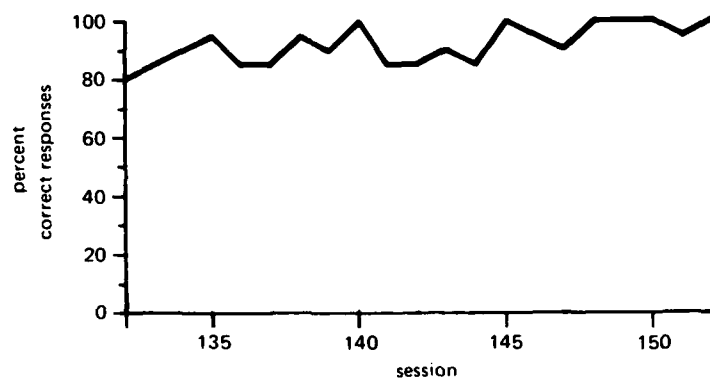
# APPENDIX C: Performance Curves - Set 3



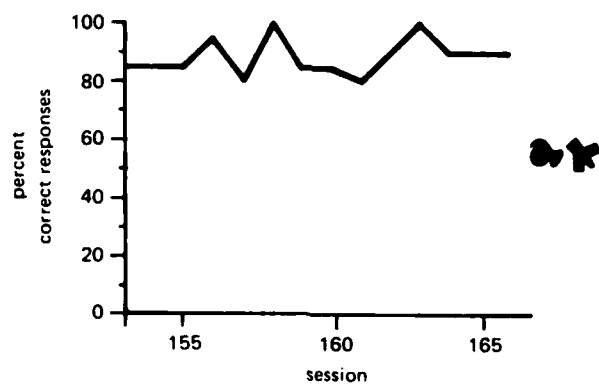
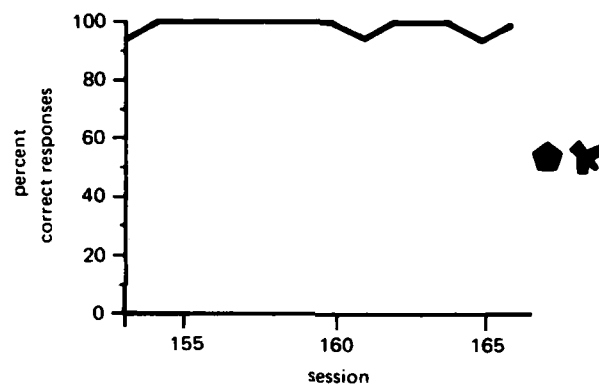
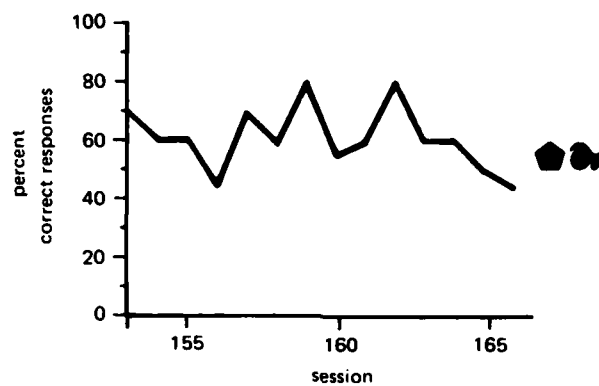
# APPENDIX D: Performance Curves – Set 4



# APPENDIX E: Performance Curves - Set 5



# APPENDIX F: Performance Curves - Set 6



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